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SCIENTIFIC ILLUMINATION

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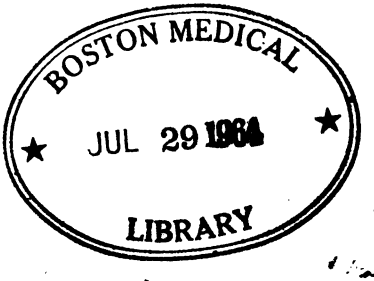
The PEOPLES GAS LIGHT & COKE CO.
Chicago, Illinois
Return to Room 1601 Gas Building



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SCIENTIFIC ILLUMINATION

Chicago and Northwestern Railroad Station Chicago. A daylight view of an excellent installation which combines direct and semi-indirect illumination.

SCIENTIFIC ILLUMINATION

GOOD LIGHT AS AN ASSET

HOW TO GET IT AT RIGHT COST

1911

MACBETH-EVANS GLASS COMPANY

PITTSBURGH

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Appreciation

The authors of this book wish to express their appreciation of the courtesy of General Electric Company, Cooper-Hewitt Electric Company, H W Johns-Manville Company, Public Service Gas Company, Newark N J, Westinghouse Lamp Company, I P Frink, The Illuminating Engineer, Pierce-Richardson & Neiler, and Frost & Granger, who have kindly offered the use of some of the illustrations contained herein.

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Why this book?

THE demand for scientific and economical lighting is spreading rapidly, and a number of technical books on the subject have recently been published. But, unfortunately, little of this printed information is intelligible to the layman.

There seems to be need of a brief, clear, accurate statement of the main facts, such as any business man may find suggestive and useful.

As it is with electricity that scientific illumination meets its greatest problems, this book deals mostly with electric lighting, although the services of our Illuminating Engineering Department are at the disposal of users of every form of illuminant.

Good Light as an Asset

Measuring results in dollars and cents, scientific illumination is a valuable asset. It appears on the ledger as maximum office efficiency, with minimum office force; maximum factory output, with minimum of "rejects" and "seconds"; maximum satisfaction of customers, consumers, clients — everyone to whom you furnish goods or service—with minimum of complaint and trouble; maximum of health and comfort for yourself, your employees, your customers, with minimum of worry, annoyance, and expense; maximum of light to use, with minimum of current to pay for.

The value of good illumination is not generally realized because it is so subtle. People feel it unconsciously. They avoid a store that is harshly or inadequately illuminated. They avoid harsh lighting just as they avoid noise. On the other hand in a store where the illumination is quiet but effective, they stay longer, do their shopping better, and buy more without knowing why.

They speak well of the store and visit it often.

The same thing applies to restaurants and other places where the comfort of customers is money in your pocket. It is even true of railroad stations and trains; for public service corporations are becoming more and more alive to the money-value of making their customers comfortable.

The cash value of good illumination in efficiency of employees cannot be over-estimated. They work better and with less strain when they have just the kind and quantity of light suited to their work. Their eyes are better, their health is better, their heads are clearer. They don't get sick so often and stay away. The out-put is better, and there is more of it.

An Asset Without Extra Cost

Usually poor lighting is not a matter of stinginess but of poor planning. It is common to have heavy bills for electric current without getting good light.

Waste

Illumination, good or not good, often costs more than it ought to. Scientific illumination stops waste and reduces bills. It produces, at lowest possible cost, the proper amount of light of the kind desired, and places it where it is useful.

By correct illuminating engineering, it is generally possible to add 25 to 50 per cent to the usable illumination from the same current. It is a business matter, and all that is necessary is to apply to the lighting problems the same common sense and forethought, supplemented by the same sort of expert advice, which is at the bottom of all great modern successes.

When once a scientifically correct installation has been planned it is simply a matter of developing it if changes are needed later. The original plan will provide for this.

Incorrect lighting equipment, already in place, can also be made more efficient and economical by the introduction of correct methods.

Showing the effect of light and dark wall-coverings upon illumination. Both booths are equipped in the same manner except the walls. Dark walls waste illumination.

How to Get Good Light

Four points to be considered are:

First: Kind of Light Required.
Second: Wiring and Outlets.
Third: Right Lamp.
Fourth: Distribution of Light.

Kind of Light Required. The first thing to consider is the nature of the space to be lighted, and the purpose for which it is used. Some uses require general even illumination; others require more light in the lower part of the room; others require that most of the light shall be concentrated in certain spots; while others need combination of general and local illumination.

Public rooms, for instance, such as reception-rooms, general business offices, and restaurants, and most of the rooms of any residence, call for lighting that leaves no dark corners and no unpleasant shadows but enables the eye to see everything agreeably and without strain. On the other hand, in drafting-rooms, workrooms, factories, etc, most of the light should be thrown directly upon the desks or machinery, while in such

places as waiting-rooms and banking-rooms a person should be able to see well enough to read anywhere, but an emphasis of light is needed at ticket-windows, news-stands tellers' wickets, and so on. Store illumination often requires several kinds of lighting.

To get proper illumination, account must be taken of every detail of the room which may affect light: length, breadth, and height; the coloring of walls, ceiling, and hangings; location and size of windows, of beams, and of projections or irregularities of any sort; the character of furnishings. All these make a great difference. In store-illumination, the kind and quantity of merchandise is a very important factor, and so is the way it is displayed, whether in show-cases, or on tables, in wall-cases, or hanging from racks.

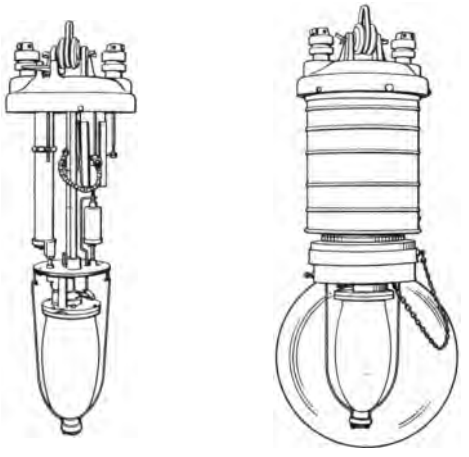
Wiring and Outlets. It is not always possible, of course, to know, in advance, the precise use that may be made of every room in a large building, nor all the details of furnishing and arrangement which may be altered from time to time. So, at the outset,

there should be provided enough wiring and outlets where lamps may be easily attached to take care of the maximum possible requirements, even if this equipment is not needed for immediate use.

Switches. It is also well to have such control of the lights that part or all of them may be used at a time, as on some occasions more illumination is desired than at other times. This can be arranged by proper switch connections; but a separate circuit for each variation is necessary and should be included in the initial installation. It is also desirable to have a switch near the door of a room or office, so that on entering or leaving the lights may be turned on or off. The small extra cost of switches may save very heavy after-costs.

The Right Light. There are several kinds of good electric lamps, each for its purpose. In some cases it is very clear that a certain lamp will give the best results in a given place. In other cases it is not so

Union Station Washington D C Illustrating indirect illumination.



Enclosed Arc Lamp

clear. The advantages and disadvantages of each kind of lamp are given below.

There are three typical forms of electrical illuminants each with several variations: the arc, the luminescent, and the incandescent.

The Arc Lamp. Broadly speaking there are two kinds of arc lamps available for indoor use. The more familiar is the *Enclosed Arc* lamp, giving a bluish-white light emanating principally from the incandescent terminals of the carbon electrodes.

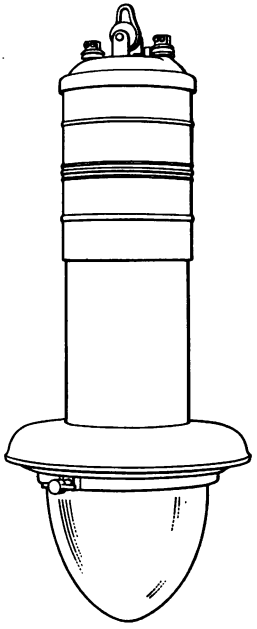
The other is the so-called *Flame Arc* lamp, in which the electrodes contain chemicals that are vaporized by the heat of the arc. These vapors cause the arc between the electrodes to be intensely luminous.

The rays of the ordinary blue-white arc are too glaring to be satisfactory for indoor lighting except in special cases. When modified by enclosing the electrodes in a translucent globe, this type of arc can be used to advantage in some large spaces of considerable height where bright general illumination is the chief need. The illumination of the *Enclosed Arc*, like that produced by all arc lamps, is somewhat unsteady and changes color values to a noticeable extent. This makes it trying to the eyes and affects its usefulness where accuracy is required. The lamp requires considerable attention, with frequent renewals of carbons, which means considerable handling of globes with resulting breakage. In spite of these defects, it is, on account of its efficiency, the form of lamp most used at present for general illumination of large interiors, although as will be seen

hereafter, arcs are being rapidly replaced by large Tungsten units for this purpose.

In some places the *Enclosed Arc* may be combined with other lamps to give excellent effect.

The *Flame Arc* Lamp is more efficient than the carbon arc, but the gas it creates is noxious and vitiates the air. The disintegrating electrodes cause a dust to settle thickly on the globe, obscuring the light and necessitating frequent cleaning.



Flame Arc Lamp

The rays of the *Flame Arc* have the special quality of penetrating smoke and steam as no other artificial light will do, making it of great value in foundries and in shops where the air is filled with obscuring vapors; for in such places there must be

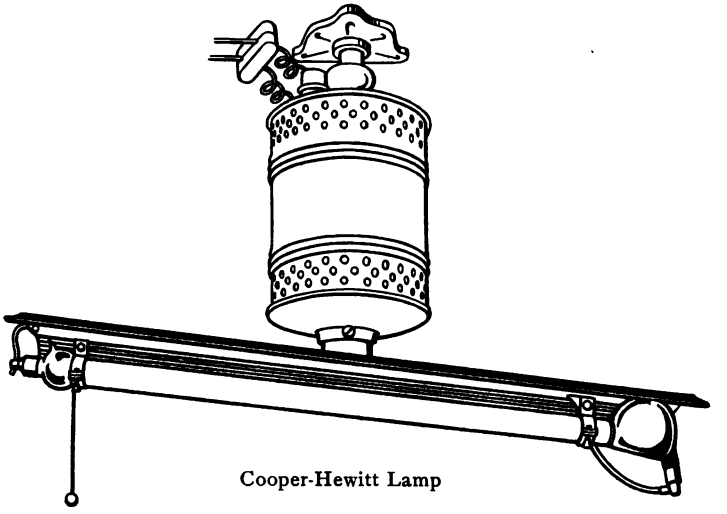
General illumination — John Wanamaker Philadelphia.

perfectly free ventilation to keep the atmosphere at all clear and this will carry away the gases from the lamp also.

As the electrodes are rapidly consumed, and are very expensive, and as it requires an inordinate amount of cleaning, the *Flame Arc* is costly to maintain. This cost of maintenance has restricted its use even in outside illumination, for which it is very satisfactory in many ways.

The *Luminous Arc*, a third kind of electrode lamp, gives a white light of very high efficiency highly suitable for street lighting, but is seldom used indoors. As with the *Flame Arc*, there is a vapor thrown off by an element mixed into one of the electrodes. The *Luminous Arc* cannot be operated in small units with economy and its glare is unpleasant in enclosed places. The form of this lamp used in direct current circuits is familiarly called the magnetite arc; that used in alternating current circuits is known as titanium-carbide arc.

Luminescent Lamps. For certain purposes, luminescent lamps are highly



Cooper-Hewitt Lamp

efficient. The kind in most general use is the mercury vapor lamp, of which the *Cooper-Hewitt* lamp is typical. Mercury vapor, confined in a glass tube, is rendered incandescent by the passage of an electric current from an iron electrode at one end of the tube to a similar electrode at the other end. It gives a blue-green illumination without sharp shadows. This light is steady and sharpens the outlines of objects on which it falls. This gives it obvious merit for Post Offices, composing-rooms, drafting-rooms,

shops with small and intricate machines, photographing by night, etc. This lamp when used in connection with a colored reflector back of the light, and an Alba Bowl covering the light, produces an illumination closely resembling daylight.

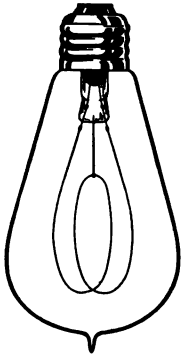
The other conspicuous luminescent light source is the *Moore* lamp. This consists of a glass tube filled with vapor which is made incandescent by passing an electric current through it. The composition of the vapor affects the color of the light, one illuminant producing a yellowish, another a reddish-pink, glow, while still others are possible. For physical reasons an extraordinary length of tube is required for efficiency, and it is apparent that the light is not susceptible of direction or concentration.

Incandescent Lamps. For some time the incandescent lamp has been gradually displacing the arc. It requires little attention, having no electrodes to be renewed. It gives a more agreeable light, creates no gas, consumes no air, and causes no dirt. It burns steadily and evenly and is adapted to all

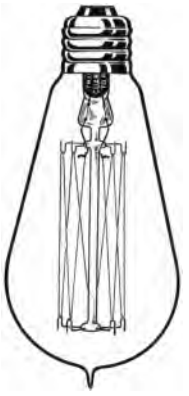
positions and conditions. Its light is also more susceptible of concentration and direction.

The commonest—and it was the earliest—type of incandescent lamp consists of a loop of carbonized material, called a filament, inclosed in a vacuum where it is heated to incandescence by the electric current. The brilliancy of its light depends on the degree of incandescence to which the filament can be heated. Carbon evaporates before reaching the melting point; so carbon filaments deteriorate long before they reach the incandescence they might otherwise attain, and thus their brilliancy of light is restricted.

Ever since incandescent lamps were invented, there has been constant search for filament material capable of high incandescence without deterioration. The best so far discovered are two metals: *Tantalum*, which is found in some quantity in Europe and is used there to a



Carbon Incandescent



Tungsten Lamp

considerable extent in making filaments, but is not common in the United States; and *Tungsten*, which is produced in this country and is being employed here more and more.

Tungsten makes the most efficient filament yet devised, and science has toughened the slender wires that, in the early lamps, gave some trouble because of their brittleness. As compared with carbon, Tungsten requires less than half as much current to produce the same degree of light. The illumination from a Tungsten lamp of large size not only is much more brilliant than that of a carbon filament, but closely approaches the intensity of an ordinary arc lamp. It is whiter than the light of an incandescent carbon filament, and so perhaps a little less agreeable to the eye, but it is much more agreeable than arc illumination.

Local illumination New York *Times* composing-room

Large Tungsten units, enclosed in diffusing globes, are rapidly displacing the arc lamp for general illumination of interiors, and, to some extent, even in exterior lighting. When all costs are taken into consideration —installation, maintenance, and current— the expense is about the same as for the arc. But the Tungsten requires less care, is cleaner, gives better color-values, is steadier, lends itself to simpler and handsomer installation, requires no expert to repair, may be renewed instantly, and therefore causes no delay.

It should be borne in mind that the filament of the incandescent lamp deteriorates after a while. To maintain the efficiency of illumination, an incandescent lamp that has noticeably lost brilliancy should be replaced. A carbon filament lamp, for instance, should be replaced after burning from 500 to 700 hours. Most people burn their lamps too long.

Distribution of Light

There are four methods of lighting a room:

Concealed Illumination
Indirect Illumination
Semi-indirect illumination
Direct Illumination

Concealed Illumination is the form in which the source of light is entirely hidden from view, and the light is thrown directly upon the object to be illuminated. This method is used when it is desirable to hide the light source and at the same time to have a maximum of light upon the object to be illuminated. It is used very successfully in shop-windows and show-cases.

Indirect Illumination is the form where the source of light is entirely hidden, but the light itself is thrown to the ceiling and walls to be reflected and diffused by them throughout the room. This method is employed in some theatres, large rooms, public halls, and like places, partly for the restfulness of having no brilliant spots constantly in the field of vision. This is feasible only where ceiling and walls are of light tint, for objects that are commonly spoken of as light-colored reflect while dark objects absorb light. No matter how good the reflection may be, there must necessarily be considerable loss of efficiency as compared with direct lighting. To obtain a given amount of brilliancy, therefore, more current must be consumed.

One fault of indirect illumination is the absence of shadows. A certain amount of shadows is necessary, for they produce the differences in intensity by which the eye readily distinguishes objects and accurately measures their position and dimensions. The lack of shadows can be offset by an occasional local direct light.

Semi-indirect Illumination is the form where part of the light is thrown by a glass bowl or dish to the ceiling and walls and thence reflected and diffused by them throughout the room, while the rest of the light is diffused by direct transmission through the glass. It is the best compromise between direct and indirect lighting, as it gives sufficient shadow and wastes less light through absorption than the indirect. It is not, however, so economical as well executed direct lighting, which, for obvious reasons, is the most used. On the other hand, the semi-indirect method is more economical than the indirect, gives the most agreeable general illumination, and can be done very handsomely—as may be seen in the picture on page 34.

Direct Illumination is that form where the lamps are in sight, and their light is distributed immediately from them. This is the most common method because of its greater economy. Local illumination, which concentrates the light on a broad object—such as a reading or drafting-table, a desk,

or machine — without reference to general illumination in the room, is a particularized form of direct illumination.

The efficiency of direct illumination, given the proper wiring, outlets, and switches, is a matter of fixtures, globes, and shades — but particularly the globe or shade because the brightest light can be almost smothered into nothing by the wrong shade, or on the

Concealed illumination — George G Benjamin New York.

other hand can be intensified so much that the eye cannot stand it.

The Fixture. The purpose of the fixture is to hold the lamp in the position from which the light may be directed to the greatest advantage. The temptation to make decorative features of fixtures often results in an elaboration of design at the expense of effective illumination. The light is thrown in the wrong direction; the fixture gets in the way and causes shadows; the cost of installation is made unnecessarily great. The fixture should hold lamps at the proper distance from walls, floor and ceiling, with consideration for the color or the covering of each, and at the proper angle for directing the light to the most advantage. Fixtures not only should be appropriate; they should be so well suited to their surroundings and purpose as to be entirely inconspicuous.

The Holder. Given a proper fixture, it is of the utmost importance that the shade-holder should be right. For, if it

Direct illumination — McAllister Brothers Motor Company Pittsburgh.

holds the shade so that the lamp is set too far into it, the light is smothered, that is, reflected back upon itself within the shade instead of being thrown out into the room; and most of the light can get out only by transmission through the glass. On the other hand, if the holder allows the lamp to project beyond the shade, there is a serious loss of both reflection and diffusion and the bare filament is trying to the eyes.

Globe, Shade, or Reflector. This is an extremely important subject, and one where, at present, occurs the greatest loss in illumination.

To understand the effect of the shade or reflector, we must consider first, the different kinds of glass, and how they affect light, and second, the effect of shape.

Glass does three things to light: transmits; reflects; or absorbs. Absorption is waste. Nobody wants more than he can help of that. Better not create the light; better keep your money. Nevertheless there is necessarily more or less absorption.

Direct illumination — McAllister Brothers Motor Company Pittsburgh.

Reflection sends the mass of light where you want it.

Transmission lets the light through, to give the general illumination desired. Direct transmission (clear glass) sends the light through without change of direction or quality and hurts the eyes. Diffused transmission (diffusion) scatters the rays and

Semi-indirect illumination by Alba Bowls. The handsomest method, giving agreeable general illumination, with comparatively small sacrifice of efficiency.

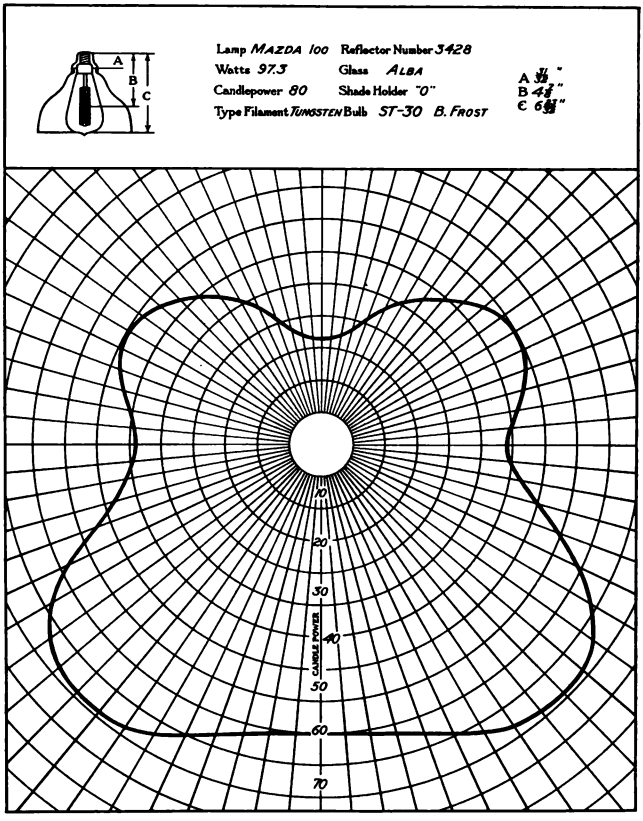
saves the eyes, with more or less waste of light by absorption.

For general purposes the ideal distribution of light is a combination of reflection and diffusion, throwing a strong light where special illumination is needed, at the same time spreading a more subdued general light around this area, thus removing the objection of an isolated bright spot which disturbs the eyes.

The four typical forms of glass used in making globes and shades are Clear glass, Frosted glass, Opal or Milk glass, and Prismatic glass. It is to be remembered that the more light a globe or shade absorbs the less there will be to reflect and transmit; and, conversely, the less it absorbs, the more light it will give.

Clear glass can do no more than protect the illuminant, as is illustrated in the globes used on many arc lamps. It simply lets the light through and does not even hide the brilliant points of light.

Frosted glass, which diffuses, is not satisfactory because it absorbs a great deal of

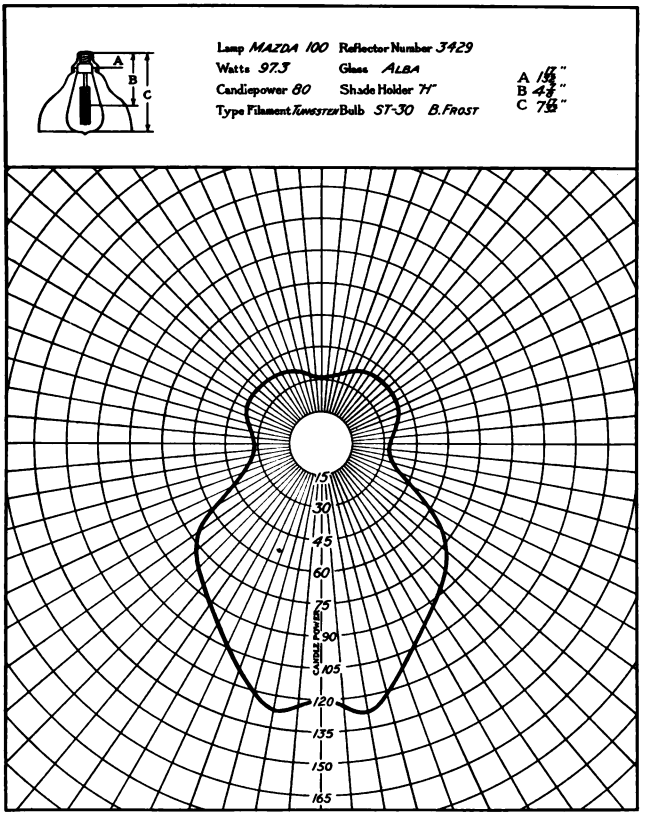


"Distributing" shade and its photometric curve. See pages 39, 41, and 42.
"Distributing" means: sending the light over a large area.

light and quickly accumulates dust and dirt on its roughed surface. This, by obstructing still more the passage of the light, causes increased absorption, which is waste.

Ordinary Opal or Opalescent glass, while it has a high degree of diffusion and reflection, has at the same time so great an absorption that it is wasteful.

Prismatic glass, when new, is the best reflector known next to a silver mirror; and when quantity of light is wanted, without regard to softness or agreeableness, it is, when new, the most efficient. Its defects, however, are many. The glare from prismatic shades is trying to the eyes if not positively harmful. Against this injury the eye defends itself by closing the pupil, thus causing what amounts to a waste of light. In order to offset these difficulties some manufacturers of this shade frost the inner surface. This lays the prismatic shade open to the same objection of wasteful absorption as the frosted globe, which objection is intensified by the collection of dust and dirt. Due to the construction of these shades, frequent cleaning



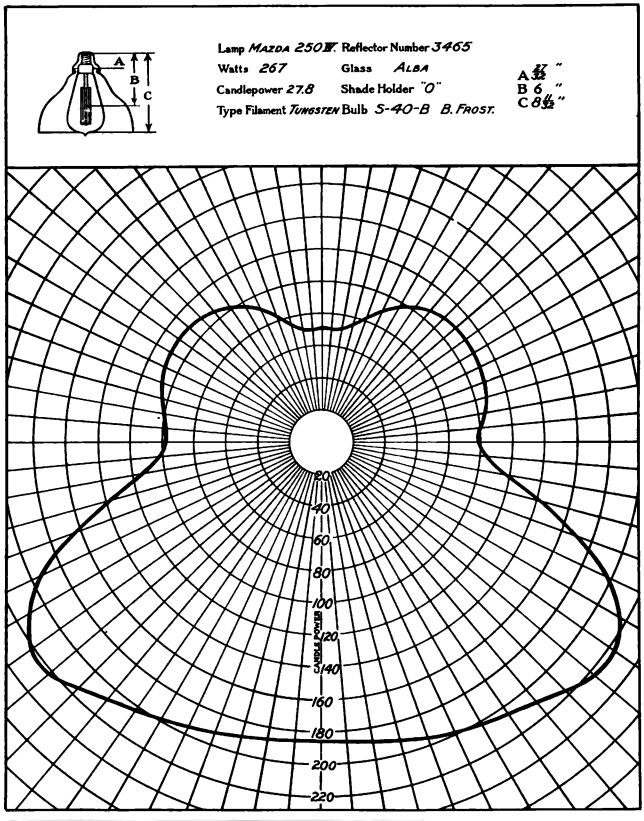
"Concentrating" shade and its photometric curve. See pages 39, 41, and 42. "Concentrating" means: placing the light mostly within a limited area.

is required, necessitating the removal of the lamp and shade from the fixture, which means handling, and that often results in the breakage of the lamps as well as the shades.

The best combination of reflection and diffusion with the least absorption is found in Alba. This is a white glass which softens the light with very little waste, does not change the color of the light source, is an admirable reflector, without sharp shadows or offensive points of brilliancy. It has a smooth surface, which does not accumulate dirt rapidly and can be cleaned without soap or water and without removing from the fixture. It is also, in most of its forms, rather handsome, and in some forms highly beautiful and decorative.

The Shape of Shade. Glass not only modifies light, but places it — that is, distributes and directs it. This it does according to the characteristics—particularly the shape — of the shade or globe which surrounds the lamp.

The direct or absolute distribution of light by a shade is graphically shown by



"Extensive" shade and its photometric curves. See pages 39, 41, and 42. "Extensive" means: directing the light over a very wide area.

what are called "photometric" or "polar distribution" curves. Typical curves, with the shades, globes, or reflectors which produce them, are shown in the accompanying illustrations, and indicate the distribution of light in a vertical plane, the lamp being considered as hung tip downward at the center of the diagram.

The distance from the center to any point upon the curve is a measure of the candlepower in that direction, which may be easily read off by means of the equally spaced concentric circles on the diagram. These curves form a convenient basis for the planning and calculation of illumination. They show to the consumer, first, whether the directed light be diffused sideways, with nearly the same intensity in every direction; whether it be distributed mostly below the shade in a broad cone of rays; or whether it be concentrated fan-fashion directly downward beneath the shade. Second, they show just how intense is the light which is being sent, in various directions, towards the objects to be illuminated.

Thus, from the judicious use of the photometric curve, supplemented with suggestions from competent illuminating authorities, one can be led to the choice of the right shape of shade for any particular case and can feel confident of obtaining the full value of illumination as calculated from such curves. Moreover, wherever the curve shows a fair proportion of light being transmitted through the sides and upper portions of the shade, one may know that there is a large margin or "factor for safety" applicable to the calculated values, due to the large amount of general illumination from ceiling and wall reflections.

Home Illumination

Proper illumination is even more rare in the home than in the office or shop. There seems to be a feeling that nothing need be scientifically correct in the home, though nowhere else is artificial light used so much or in so many different ways, or during so many hours in the twenty-four.

It is hardly too much to say that, in most homes, the electricity bills could, by correct

illuminating engineering, be reduced one-third. But the most important result of bad lighting in the home is the strain and injury of eye, mind, and body.

Just as scientifically correct illumination saves time and money in a business establishment, it saves health and increases comfort in the domestic establishment. Judicious illumination has been sacrificed frequently, however, to supposed artistic effect by the use of too ornate fixtures, fancy shades, parti-colored globes, or what-not. These look very well sometimes, but when comparison is made with carefully designed globes, fixtures, and lamps, properly placed, and in harmony with surroundings, the so-called ornamental lights are hardly attractive individually. Science can be applied to sane decorative effects in residence lighting as well as to economical principles in commercial lighting. Nowhere can good light accomplish more than in private residences, either by its beneficial effect on people who have to use it, or by its enhancement of beauty and decoration of surroundings.

Physiology of Lighting

The physiological effects of lighting must also be considered.

Good lighting is such that a person is as unconscious of it as he is of daylight. That is to say, it is so entirely a part of his surroundings that he does not give it a thought one way or the other. He should be able to see by night as well as he does by day, since that makes for accuracy, preventing blunders, spoiled product, and so on; and it saves the mind, nerves, and body, from unnecessary exhaustion, helping to keep them alert and energetic.

The bare light-source should never be exposed to the eye. It dazzles and strains the eye and prevents clear vision. This not only defeats the purpose for which the light was created, but does actual harm.

There should be a certain amount of diffused illumination even when most of the light is concentrated — for use upon tables or machinery. Conversely, in general illumination by indirect lighting, it is a relief to most people to have a few appropriate lamps

or light groups in the field of vision. The mind is accustomed to tracing cause back to effect, and not being able to do this is disturbing. So the restfulness and comfort

Indirect illumination. Entrance way to Capitol, House side, Washington, D. C.

given by indirect illumination are generally increased by apparent light sources, even though they do not actually contribute much to the light supply. In the same way, a

certain amount of shadow is desirable, since shadows are essential for producing the differences in intensity by which the eye readily distinguishes objects and accurately measures their position and dimensions.

While comfort is the most immediate and apparent result of giving weight to such considerations as these, the proper degree of comfort is so essential to efficiency that the physiological effects of lighting are very practical factors in good illumination. The mind that works easily and the hand that works accurately are many times as valuably productive as the mind and body working in conditions that impose a constant strain. Frequently the strain is suffered unconsciously for a long while, but its effects show persistently in costly ways. To give right lighting its full value as an asset, it is necessary to attach as much importance to the physiological facts involved as to the more obvious dollars-and-cents comparison of cost and quantity of illumination. It is the careful weighing and proportioning of all these considerations that go to

make up practical, scientific illuminating engineering.

Gas. Problems of illumination by gas are quite similar to those of illumination by electricity. The general principles that have been laid down here are therefore entirely applicable to them. It may be said in addition that the inverted mantle burner has made it possible to get a high degree of illumination by gas and to manipulate the light to a considerable extent.

Your Particular Need. The information given in this book must be, of course, suggestive and very general.

If you are dissatisfied with your lighting —and most people should be—we invite you to write to our Illuminating Engineering Department at Pittsburgh stating what your illuminant is—gas, electricity, etc.—whether for house, office, store, factory, railroad station, public building, Pullman car, or whatever else it may be. We shall then send you a blank to fill out in regard to your situation and after careful study

we shall make specific recommendations which should result in better and more economical lighting.

We are glad to do this on the chance that you may use one of the 2,000 or more kinds of glass we furnish for lighting purposes.

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